WFIRST: WHAT IT IS \textit{NOT}

- a dark energy mission
- an exoplanet microlensing mission
- an infrared sky survey
- the creation of Astro2010
- Euclid
WFIRST: WHAT IT IS

A Wide-Field Infrared Survey Telescope

imager to 2.4 $\mu$m with $2 \times 10^8$ HgCdTe pixels

a 205K unobstructed three mirror anastigmat slitless spectrometer: $R = 75$ & $R = \frac{200''}{\theta_{FWHM}}$
General Considerations

\[
\left( \frac{\text{solid angle}}{\text{angle}} \right) = \left( \frac{\text{diffraction limit}}{1.5} \right)^2 \times \left( \frac{\text{number of pixels}}{\text{focal ratio}} \right)
\]

\[
\left( \frac{\text{focal ratio}}{\text{ratio}} \right) = \left( \frac{1.5 \times \text{pixel size}}{\text{wavelength}} \right)
\]

“1.5” is a subject of great debate
WFIRST’s Multiple Incarnations

<table>
<thead>
<tr>
<th>version</th>
<th>DATE</th>
<th>diameter</th>
<th>obstructed</th>
<th>red limit</th>
<th>number cameras</th>
<th>detectors</th>
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<tbody>
<tr>
<td>JDEMO</td>
<td>2010</td>
<td>1.5-m</td>
<td>yes</td>
<td>$2.1\mu$</td>
<td>3</td>
<td>36 H2RG-18</td>
</tr>
<tr>
<td>IDRIM</td>
<td>2011</td>
<td>1.3-m</td>
<td>no</td>
<td>$2.1\mu$</td>
<td>3</td>
<td>36 H2RG-18</td>
</tr>
<tr>
<td>DRM1</td>
<td>(2012)</td>
<td>1.3-m</td>
<td>no</td>
<td>$2.4\mu$</td>
<td>1</td>
<td>36 H2RG-18</td>
</tr>
<tr>
<td>DRM2</td>
<td>2012</td>
<td>1.1-m</td>
<td>no</td>
<td>$2.4\mu$</td>
<td>1</td>
<td>14 H4RG-10</td>
</tr>
</tbody>
</table>
Design Reference Mission Options

- **IDRM**
  - 1.3 meter off-axis telescope
  - 3-channel payload
  - 5 year mission
  - Atlas V Launch Vehicle

- **DRM1**
  - 1.3 meter off-axis telescope
  - Single channel payload
  - 5 year mission
  - Atlas V Launch Vehicle

- **DRM2**
  - 1.1 meter off-axis telescope
  - Single channel payload
  - 3 year mission
  - Falcon 9 Launch Vehicle
Planetary Microlensing

Galactic Center

8 kpc

1-7 kpc from Sun

Sun

Light curve

Source star and images

Lens star and planet

WFIRST
\[
\left( \text{uncertainty in local mean image ellipticity} \right) < 0.0005
\]
Cosmic Acceleration History
DRM1 Capabilities

- BAO/RSD: covers >1400 deg² per year to a limiting Hα flux of $1 \times 10^{-16}$ ergs/cm²/sec (7σ) at resolution $R = 600$ over the redshift range $1.3 < z < 2.7$.

- Weak Lensing: covers >1400 deg² per year to a limiting magnitude $AB = 26$ each in the Y, J, H and K filters yielding 30 galaxies/arcmin² in J, H and K.

- SNe-Ia: 2 tiered survey covering 6.5 deg² and 1.8 deg² with a five day cadence over 1.8 years yielding \(~100\) SNe per $\Delta z = 0.1$ bin for $0.4 < z < 1.7$. 
WFIRST provides a factor of 100 improvement in IR surveys
NOTIONAL GENERAL
INVESTIGATOR PROGRAMS

Search for Kuiper Belt objects
Open cluster mass functions to $25M_{Jup}$
Stellar populations in nearby galaxy halos
Lower main sequence in globular clusters
Channel field layout for WFIRST DRM1

1.3m uTMA, 9x4 single channel @0.18”/H2RG pixel

The Field of view of the single imaging & spectroscopy channel is shown to scale with the Moon, HST, and JWST. Each square is a 4Mpix vis-NIR sensor chip assembly (SCA)

WFIRST-JWST Focal plane Comparison

• Area is 145x larger than NIRCAM (0.375 vs. 0.00259 sq degrees
• Focal plane has 5x more pixels than NIRCAM short wave cameras (150 vs 33 Mpix)
Channel field layout for WFIRST “DRM2”

The Field of view of the single channel which can be used in imaging (Im), BAO spectroscopy (Sp), or SN spectroscopy (SNSp) mode is shown to scale with the Moon, HST, and JWST. Each square is a 16Mpix vis-NIR sensor chip assembly (SCA), 10 um pixels.

WFIRST-JWST Focal plane Comparison
- Area is 226x larger than NIRCAM (0.585 sq vs 0.00259 degrees)
- Focal plane has 7x more pixels than NIRCAM short wave cameras (235 vs 33 Mpix)
WFIRST DRM2
Observatory Layout

- Sun is at bottom in this view
- WMAP-like progression from warm solar array (300K) to cold focal plane (100K) from bottom to top
- Overall dry mass 500+ kg less than DRM1
Cost Estimates

- The WFIRST Independent Cost Estimate by Astro2010 (based on JDEM configuration) was $1.6B

- The Project Office cost estimates indicate that DRM1 would have a full cost less that $1.6B due to single instrument channel and reduced mass.

- The Project Office cost estimates indicate that DRM2 would have a full cost of <$1B due to the smaller telescope, significantly reduced mass, 3 year operation, Falcon 9 launch

- NASA HQ has funded the Project for an Independent Cost Estimate of DRM2. That is in work, with results expected by end of the summer.
Conclusion

- The SDT and Project have completed the action of developing two compelling mission concepts.
- DRM1: Fully responsive to the objectives of NWNH at reduced cost.
- DRM2: Extraordinary low-cost near-infrared survey opportunity. The limited 3 year life precludes full compliance with NWNH goals.
- Recommended path forward:
  - The optimizations developed for DRM2 indicate that there is a scientifically compelling, medium-cost trade space, for developing a near infrared survey mission.
  - Refine the innovations developed in DRM2 into a “DRM1-like” mission concept; determine whether performance of this new concept can be fully responsive to NWNH.

- **DRM1 and DRM2 are both compelling opportunities for wide-field near-infrared surveys of critical importance to a broad spectrum of astronomical disciplines.**
- **Incorporating the optimizations that enabled DRM2 into DRM1 has the potential of creating an extraordinary opportunity to deliver the science required of NWNH at a medium class budget.**
SCIENCE DEFINITION TEAM

Charlie Baltay        Chris Hirata        Paul Schechter
Rachel Bean           Jason Kalirai      Dan Stern
David Bennett         Tod Lauer          Takahiro Sumi
Bob Brown             Bob Nichol         Angelle Tanner
Chris Conselice       Nikhil Padmanabhan Wes Traub
Megan Donahue          Saul Perlmutter    Yun Wang
Xiaohui Fan           Bernie Rauscher    David Weinberg
Scott Gaudi           Jason Rhodes       Ned Wright
Neil Gehrels          Tom Roellig        Rita Sambruna
Jim Green             

STUDY OFFICE: Richard Barry, Ed Cheng,
Dave Content, Kevin Grady, Cliff Jackson, Jeff Kruk,
Mark Melton, Norm Rioux
Figure 7: Monochromatic diffraction for unaberrated pupils. Top: an unobscured pupil. Bottom: pupil obscured by a centered 50% linear disk and three spider legs. Pupils are shown at the upper left. Logarithmic vertical scale spans four decades. Fresnel-Kirchoff diffraction assumed.
Fig. 3. — Examples of AGN host galaxies that were classified as having spheroid and disk morphologies, as well as two galaxies experiencing disruptive interactions. Thumbnails on the top row are WFC3/IR images taken in the F160W (H) band (rest-frame optical), while those on the bottom row are from ACS/WFC in the F775W (i) band (rest-frame ultraviolet). These images demonstrate that accurately classifying the morphology of these galaxies at $z \sim 2$ requires $H$-band imaging.
## WFIRST – Euclid Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>WFIRST</th>
<th>Euclid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirror diameter</td>
<td>1.5m (effective)</td>
<td>1.2m</td>
</tr>
<tr>
<td>Visible imager</td>
<td>none</td>
<td>36 CCD's</td>
</tr>
<tr>
<td>NIR imager spec</td>
<td>0.75x36 HgCdTe's</td>
<td>0.25x18 HgCdTe's</td>
</tr>
<tr>
<td>NIR pixel scale</td>
<td>0.18 &quot; / pixel</td>
<td>0.30 &quot; / pixel</td>
</tr>
</tbody>
</table>

### Diagrams

- **BAO errors**: Shows relative H error (%) vs redshift for WFIRST and Euclid.
- **Euclid vs WFIRST**: Comparisons of spheroids, disks, and mergers/interactions.

*Source: Wang & Bennett 2011*